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Towards greener airport ground movement

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LANCS Workshop 2014

Introduction

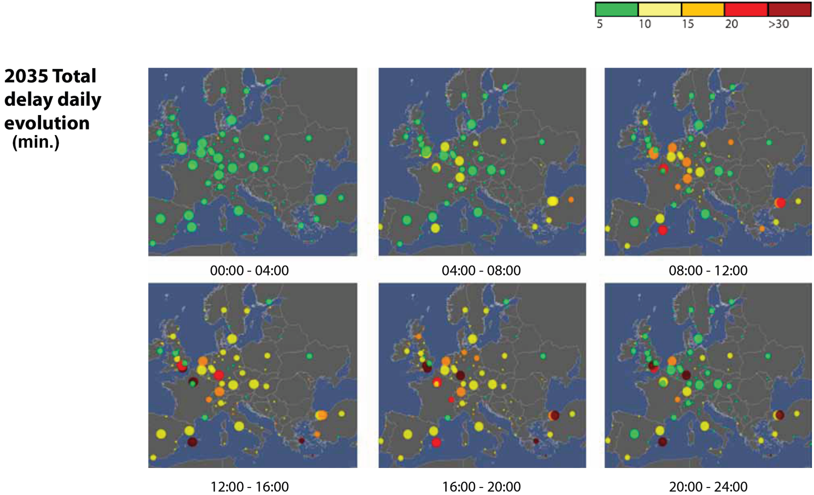


Figure: Predicted situation in 2035. Source: EUROCONTROL.

The need for efficient airport operations

- In 2035, air traffic volume is expected to be 1.5 times larger than today.
- Without action, 12 % of flights could not be accommodated because of lack of airport capacity.
- At the same time, the goal for transport industry will be to reduce GHG emissions to 20% below their 2008 level.
- Long-term goals are set in Flightpath 2050: emission-free ground movement.

Ground movement: a key element

- Ground movement is one of the key operations at the airport: links other operations.
- The main goal: find routes and schedules for all aircraft moving on the airport surface in an effective manner.
- Evolution of research on ground movement:
  1. considered only the taxi time objective - minimum of changes in operation.
  2. 4D trajectory - considering also speed profile - advanced methods: SESAR and NextGen projects.
  3. speed profile optimisation - advanced methods of data sharing.

Ground movement: research directions

Research completed or planned in Lincoln:

I. accurate taxi time prediction: Chen et al. (2011),

II. multi-objective ground movement optimisation: Weiszer et al. (2014),

III. accurate control techniques.

I. Multi-objective ground movement problem

Subproblems:

1. routing and scheduling problem,
2. the speed profile optimisation problem.

Objectives:

g_1 : total taxi time,

g_2 : fuel consumption.

Routing and scheduling subproblem

Goal: to route aircraft in an efficient and conflict-free manner.

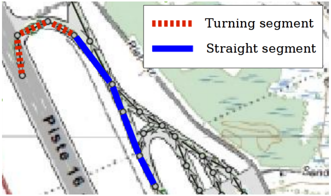


Figure: Graph representation of the airport surface.

Solution algorithm:

- the k-Quickest Path Problem with Time Windows (k-QPPTW) by Ravizza et al (2012).
- needs input from the speed profile optimisation subproblem.

Speed profile optimisation subproblem

Goal: Pareto optimal speed profiles for a given route.

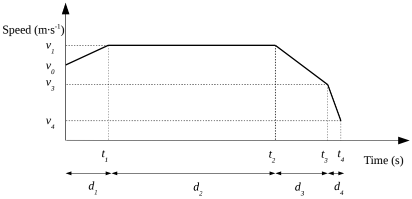


Figure: An example of a speed profile with four phases.

Solution algorithm:

- the Population Adaptive based Immune Algorithm by Chen and Stewart (2011).
- Heuristic for speed profile optimisation.

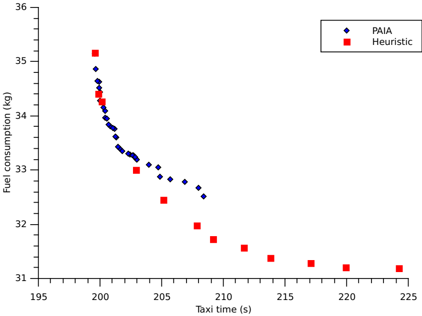
Fuel consumption model

- Based on the International Civil Aviation Organization (ICAO) engine emissions database.
- for braking and turning phase:

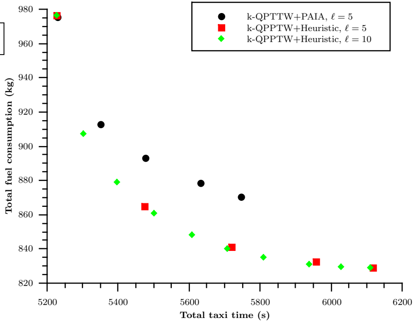
Baseline assumptions	Thrust level η of full rated power
Brake and rapid brake thrust	5%
Thrust during turning	7%

- for acceleration and constant speed phase:
- Thrust is calculated using a physics based model based on the rolling resistance of the aircraft, its weight and acceleration.

Computational results



(a) one aircraft.



(b) 26 aircraft.

Figure: Pareto fronts.

Computational results

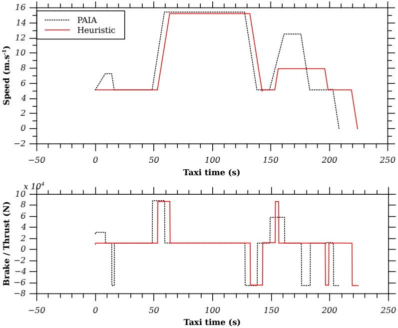


Figure: Slowest speed profile with the best fuel consumption for an aircraft, comparison of solutions found by PAIA and the heuristic.

Computational results

Table: Running times of algorithms.

Algorithm	time (min.)
k-QPPTW+PAIA, $\ell = 5$	317
k-QPPTW+Heuristic, $\ell = 5$	**6**
k-QPPTW+Heuristic, $\ell = 10$	12

- Promising for application within on-line system.

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II. Accurate taxi time prediction

- Fuzzy based system: Chen et al. (2011),
- possible application to reduce separation distances.

	± 3 min.	± 5 min.
Linear regression	95.6%	99.4%
Mamdani FRBS	98.8%	100%

Table: Prediction accuracy for Zürich Airport.

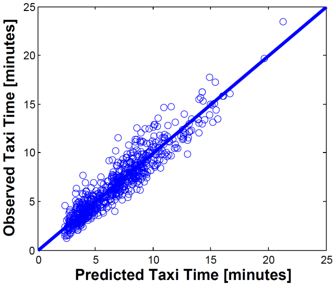

Figure: Fit of the FRBS.

Accurate taxi time prediction

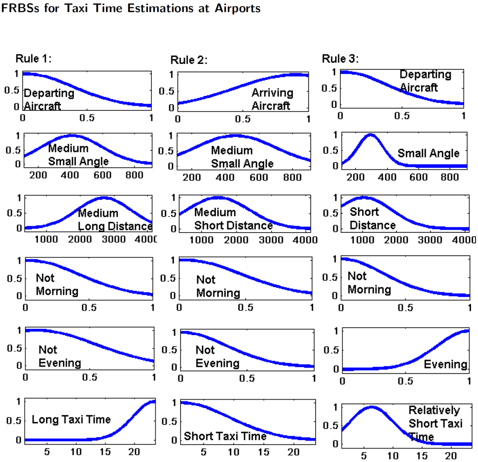

Figure: Three fuzzy rules extracted from the data for Zürich Airport.

Future directions

- A better understanding of actual fuel burn is necessary.
- Considering additional objectives: emissions, noise, ...
- Robustness and uncertainty.
- Human-in-the-loop approach/automatic taxiing.

Conclusions

- Researched areas: accurate taxi time prediction, multi-objective ground movement optimisation.
- More investigation needed to fully utilize the potential.
- Outlined future directions open new research possibilities.
- Need for industrial collaboration to verify concepts.